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PROBABLE EFFECT OF THE WAR IN EUROPE ON THE CERAMIC INDUSTRIES OF THE UNITED STATES

BY

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PROBABLE EFFECT OF THE WAR IN EUROPE ON THE CERAMIC INDUSTRIES OF THE UNITED STATES.

By A. S. Watts.

INTRODUCTION.

This country normally imports enormous quantities of ceramic materials, as well as ceramic wares, from the countries of Europe now at war. In an endeavor to increase efficiency in the utilization of the mineral resources in the United States, the following brief statement of the probable influence of the war on the ceramic industries of this country has been prepared for the information of those producers and manufacturers who are directly affected.

The chief ceramic material imported from Europe is clay, and may be classified as of two general kinds: Kaolin or china clay, and ball clay.

CHINA CLAY.

China clay constitutes by far the larger proportion of the total clay imported. The chief European kaolin-producing centers are St. Austell, in Cornwall, England; Halle am Salle, in Saxony, Germany; Zettlitz and Kariolinenthal, in Bohemia, Austria; and Limoges, France; but almost all the china clay imported comes from England.

PRESENT STATUS OF CHINA-CLAY INDUSTRY IN ENGLAND.

The total annual production of English china clay is estimated at 1,000,000 tons. Of this amount about 300,000 tons are shipped to the United States, about 200,000 tons are consumed by the industries of England, and the remaining 500,000 tons are exported to continental Europe. Of the 300,000 tons imported by the United States, only about 25 per cent is used in ceramic manufacture, the remainder being consumed in the paper, the bleaching, and other industries.

The abrupt closing of the factories of continental Europe left the English clay-washing plants with great stocks of washed kaolin on hand and also a great amount of material in the various stages of refining.

The washing of kaolin does not require a relatively large force of workmen, as the process consists chiefly of floating the fine particles of clay and removing the associated minerals by means of settling

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troughs and tanks. The work can be, and is, performed chiefly by old men and boys. In continental Europe, women do much of this work and doubtless they could in England if the call for soldiers removed the men of military age now employed in the industry.

The employees in the various ceramic factories are chiefly men liable to military service and the call to arms naturally resulted in a lessening of the labor supply. The domestic consumption of English china clay is undoubtedly greatly reduced and at least part of the stock of clay prepared for English factories is available for export.

The distance to tidewater from the Cornwall clay center is not more than 10 miles and most shipments are in cargo lots by freight steamers. As little manufactured ware is being offered for export, little difficulty is experienced in the shipment of clay. Some of the better freight steamers have been pressed into military service but sufficient remain to handle promptly all the clay demanded by American importers.

PROBABLE INCREASE IN PRICE.

A small increase in insurance on hull and cargo has been made on account of war risks, but the average increase has not yet (January, 1915) exceeded 60 cents per ton.

If war conditions result in the closing of the port of Fowey, where practically all china clay is loaded, it would be necessary to ship by rail to Plymouth, or some other port, and this would probably increase the cost 50 cents.

SUPPLY OF CHINA CLAY ON HAND IN THE UNITED STATES.

A general canvas of the ceramic industries of the United States early in September, 1914, showed that when war was declared most manufacturers feared a shortage of china clay would result, and immediately purchased as large a stock as their storage facilities would accommodate. Most of this has now been delivered. In addition about 40,000 tons of china clay was to be received at American ports prior to November 1, 1914. From the foregoing it is apparent that there is little occasion for anxiety concerning the supply of china clay from England.

The exportation of china clay or kaolin from continental Europe has been discontinued, and may not be resumed so long as hostilities continue.

BALL CLAY.

The amount of ball clay imported from Europe is much less than that of china clay, owing to the smaller proportion of ball clay than china clay in most ceramic mixtures, and also to the fact that little ball clay is used outside the ceramic industries. The total importation of ball clay does not exceed 50,000 tons annually. Of this the greater proportion comes from Dorsetshire and Devonshire, England. The ball clay imported from continental Europe is obtained chiefly from the neighborhood of Klingenburg and Aschaffenburg, in Bavaria, Germany. A small amount of plastic clay is shipped from near Budweis, Austria.

MINING SITUATION ABROAD.

The mining of ball clays is an industry employing chiefly men capable of doing military duty and hence would be more seriously affected by war conditions than the china-clay industry. The German and Austrian mines are not in operation so far as can be learned, and no clay is being exported from either country. The ball-clay mines of England are operating with somewhat reduced force, but the abnormal demand for ball clay in the United States, created by fear of a shortage, has been promptly supplied. Several thousand tons of English ball clay were loaded and shipped, all of which has been delivered.

SHIPPING SITUATION.

Shipments of ball clay are generally made in less than cargo lots and much irregularity in delivery has resulted from inability to obtain prompt accommodation on commercial freighters, owing to the low freight rate on this class of material. No serious inconvenience has resulted since the opening of the war from inability to ship English ball clay, and so long as present conditions prevail, no difficulty is expected.

PROBABLE INCREASE IN PRICE.

The increase in market price of ball clay, due to war risks in shipping, has not exceeded 60 cents per ton, and unless war risks are greatly increased the selling price of English ball clay should not be increased more than $1 per ton as a maximum.

Owing to the difference in mining conditions in the ball-clay mines as compared with the china-clay mines the likelihood of irregularity in shipping is much greater.

CORNWALL STONE.

So-called Cornwall stone, a form of pegmatite associated with the china clays of Cornwall, England, is much used in England as a ceramic flux. Its chief constituents are feldspar, flint, and an anhydrous silicate of alumina. It has some physical properties not possessed by feldspar and is especially adapted for use in making certain ceramic wares. It has been imported in considerable quantity by the United States.

There are three grades of Cornwall stone, namely, the purple, or fresh rock; the white, which is lightly weathered; and the buff, in which weathering is well advanced. As the proportion of alkali removed by weathering varies, these grades differ widely in physical properties. Caution is necessary in using Cornwall stone that the same grade is always obtained.

STATUS OF CORNWALL-STONE INDUSTRY.

The mining of Cornwall stone employs a class of men liable to military service and hence this industry, like the ball-clay industry, will suffer more from loss of miners than will the china-clay industry. The rock is shipped to the United States in the crude state and generally in cargo lots. The output of the mines has been greatly reduced, but there has been no apparent shortage of material for export. However, production will probably be more or less intermittent.

SUBSTITUTES FOR CORNWALL STONE.

Owing to its peculiar pyrometric properties, Cornwall stone has never been successfully replaced in ceramic bodies by a synthetic mixture of feldspar, kaolin, and flint, even though the chemical composition of the mixture be the same as that of the stone.

In ceramic glazes, however, the following mixture has been found to successfully replace 100 parts of purple Cornwall stone:[a]

Potash feldspar	42.84
China clay	26.71
Flint	34.24
Total	103.79

CHERT PEBBLES FOR GRINDING.

For grinding substances in ball and in tube mills American manufacturers have always depended on material from Europe—the flint pebbles found in the chalk cliffs of the French, Belgian, and English coasts. These pebbles are nodules of silica, partly crystalline and partly amorphous, that has separated from the calcareous mass by a process of aggregation. They have been imported in considerable quantity.

These pebbles have also been calcined by some manufacturers and, when ground, produce the French flint of commerce. The use of French flint has been almost abandoned in recent years; hence a shortage of pebbles will not prove serious, unless the supply is exhausted and no pebbles are available for use in the grinding of feldspar and flint.

Chert pebbles similar to European pebbles are found along the coasts of Greenland and Denmark, but these are at present as inaccessible as the French, Belgian, and English supplies. The supply has been obtained chiefly from the coasts of France and Belgium. The coast near Dover, England, can also be worked for pebbles, but the cost of handling and sorting is greater in England than in the continental countries.

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[a] Mayer, Ernest, A comparison between English and American glaze practice: Trans. Amer. Cer. Soc., vol. 16, 1914, p. 310.

No attempt has been made to replace imported pebbles by American material, although chert pebbles of similar structure occur in Colorado.

No survey has been made with the object of locating such material, but doubtless many deposits of pebbles suitable for grinding purposes are to be found in the United States, although the pebbles may differ in origin and perhaps in physical structure from the pebbles now used.

WHITE-CLAY RESOURCES OF THE UNITED STATES.

Many deposits of kaolin and of ball clay have been located in the United States, but only a small number are being worked. If a shortage of European material should develop, a number of additional properties would doubtless be opened.

The clay properties may be divided into two classes—active and inactive.

KAOLINS.

ACTIVE KAOLIN DEPOSITS.

The kaolin deposits now being worked in the United States may be subdivided into the following groups: Pennsylvania, Delaware, North Carolina, Georgia, and Florida kaolins.

PENNSYLVANIA.

All the known deposits of primary kaolins of feldspathic origin in Pennsylvania have been exhausted. There are, however, in Cumberland, Berks, and Blair Counties extensive deposits of kaolin produced by decay of limestone rocks. The kaolin has not proved suitable for most ceramic uses, although it has been employed to some extent in making brick and light-gray vitreous floor tile Practically all the clay mined in this district is consumed in the manufacture of paper. This material could not be depended on to furnish any relief to the potter in case of a shortage of European kaolins.

DELAWARE.

Primary kaolins are found in Newcastle County, Del., in dikes 35 to 50 feet wide. The clay varies greatly as regards content of impurity but in physical properties is strikingly similar to the English china clay. The best grades are used successfully in the manufacture of vitreous china and the poorer grades are used for the manufacture of sanitary ware and electrical porcelain.

The present production of Delaware kaolin is about 2,250 tons per month and could be easily increased to 4,500 tons per month if conditions demanded. The crude material in sight might justify the erection of additional washing plants if the English supply were cut off for some time.

The companies now operating in the Delaware kaolin field are given here. These names include all of which the Bureau of Mines has knowledge at the time this paper is printed.

Golding Sons China Clay Co., Hockessin, Del.
Newark China Clay Co., Newark, Del.
Peach Kaolin Co., Newark, Del.

NORTH CAROLINA.

The production of kaolin in North Carolina is distributed over a relatively large area between the crests of the Blue Ridge and the Great Smoky Mountains. Mitchell, Jackson, Swain, and Macon counties are the chief producing centers.

The kaolins of North Carolina do not resemble any European kaolin in physical or pyrometric properties. They are seemingly of more recent age and are lower in plasticity and bonding strength, but as a rule the color of the burned ware is excellent. The great obstacles to the use of much of this kaolin are its resistance to vitrification and the wide variation in shrinkage of the clay from different deposits or even of different parts of the same deposit. Variation in shrinkage can be largely remedied by an elaborate system of blending. This clay is extensively used in the manufacture of glazed wall tile and faïence.

The present production of North Carolina kaolin is about 2,000 tons per month and could be increased about 50 per cent if the demand warranted installation of increased equipment.

The companies now operating in the North Carolina field are given below. The names given include all the companies of which the Bureau of Mines has knowledge at the time of printing this paper.

Harris Clay Co., Sprucepine, Mitchell County, and Dillsboro, Jackson County, N. C.
Tuckaseigee Clay & Mica Co., Brysen, Swain County, N. C.
Guernsey Clay Co., Franklin, Macon County, N. C.

The outputs of the two companies last named are sold through the John Sant & Sons Co., East Liverpool, Ohio.

GEORGIA.

The production of kaolin in Georgia is restricted to a comparatively small area in Twiggs and Wilkinson Counties, although the deposits are scattered over a large belt extending southwest from

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Augusta to Columbus. This kaolin is secondary and is of remarkable purity, many deposits containing more than 98 per cent pure kaolin. Unfortunately, it does not burn as white as many primary kaolins and it has a peculiar physical property that causes it to resist intimate mixture with other ceramic materials. This property can be and has been overcome to a considerable degree by pulverizing the dried kaolin or by washing.

Although unsuited for the manufacture of the finest tableware, this clay is used extensively in making sanitary ware, electrical porcelain, and floor and wall tile. The bonding strength of this kaolin is superior to that of most china clays. Although its shrinkage varies slightly in different sections it remains constant over large areas of the test pieces and is about the same as the shrinkage of English china clays. The average monthly production of Georgia kaolin is about 6,000 tons and could be increased at least 50 per cent with little delay, and without a great outlay for equipment. A considerable proportion of the production of Georgia kaolin is used in the manufacture of paper.

The companies operating in the Georgia kaolin field are given below. The names include all of which the Bureau of Mines has knowledge at the time of printing.

John Sant & Sons Co., Dry Branch, Twiggs County, pulverized kaolin; offices, East Liverpool, Ohio.

Atlanta Mining & Clay Co., Dry Branch, Twiggs County; washed kaolin; offices, Atlanta, Ga.

Georgia Kaolin Co., Dry Branch, Twiggs County; washed kaolin; offices, Macon, Ga.

Edgar Plastic Kaolin Co., McIntyre, Wilkinson County, washed kaolin.

FLORIDA.

The Florida kaolin is a secondary kaolin and occurs in beds associated with large amounts of sand and flake mica. It requires the same washing treatment as primary kaolin. The chief producing centers are in Lake and Putnam Counties in north-central Florida. The Florida kaolin is much more plastic than any European kaolin and may be used as a substitute for ball clay in many industries. It has a shrinkage about midway between ball clay and china clay. The color of the burned clay is equal to that of most European china clays. It can not be successfully used as the sole clay constituent of most ceramic wares but a limited proportion of it greatly improves the working properties of most bodies without injuring the color.

This kaolin can be used to replace in part any European kaolin.

The present monthly production of Florida kaolin is about 2,500 tons and will probably be increased about 50 per cent by January 1, 1915.

So far as the Bureau of Mines has knowledge, but two companies are now (January, 1915) operating in the Florida kaolin field. These companies are: Edgar Plastic Kaolin Co., Edgar, Putnam County, Fla.; Lake County Clay Co., Okahumpka, Lake County, Fla.

INACTIVE KAOLIN DEPOSITS.

COLORADO AND TEXAS.

Two kaolin properties that have been opened and later abandoned for causes other than inferiority of product are one near Golden, Jefferson County, Colo., and one in Edwards County, Tex. The one near Golden depended on a pottery in the neighborhood for its market, and as this industry was abandoned the mining was discontinued. The deposit in Edwards County, Tex., a residual kaolin containing considerable free silicic acid, has been mined in a small way. The deposit is about 40 miles from a railroad, and the cost of transportation to the market prohibits the use of this clay in many industries. Because of this fact and the difficulty of conveying the kaolin to the railroads mining was discontinued.

MISSOURI.

In Bollinger, Cape Girardeau, Perry, and Madison Counties, Mo., deposits of a white kaolin have been opened. The kaolin contains variable amounts of finely divided flint which can not be removed by the ordinary washing process, and if used must be regarded as a mixture of kaolin and flint.

VIRGINIA AND NORTH CAROLINA.

Deposits of residual kaolin similar to that mined in North Carolina are known to exist in Virginia and on the east slopes of the Blue Ridge Mountains in North Carolina.

TENNESSEE.

In Cocke County, Tenn., a deposit of kaolin, similar to the Pennsylvania clay described, has been found and was worked for a time, but without great success.

SOUTH CAROLINA.

In Aiken County, S. C., a clay similar to the Georgia kaolin has been mined at a number of places, but has never been extensively used in the ceramic industries.

OTHER STATES.

Kaolin is also reported from Vermont, Connecticut, New Jersey, Maryland, Alabama, Arkansas, Idaho, Nevada, Utah, Washington, and Oregon, but no specific data are available as to quantity or quality.

BALL CLAYS.

Ball clays are being mined in the United States that are equal or superior to any European clays as regards color. In plasticity and bonding strength they are slightly inferior to a few but equal to most of the imported ball clays.

ACTIVE BALL-CLAY MINES.

The ball-clay mines in the United States that are now being worked are located in Calloway and Graves Counties, Ky., and Henry County, Tenn.

KENTUCKY.

The centers of the ball-clay industry in Kentucky are Calloway and Graves Counties. This clay occurs in much larger masses than do the ball clays of England and is mined by open pits, whereas in England the clay is taken out through small shafts.

The deposits are more or less stratified, yielding several grades of clay suited to various industries.

These ball clays can be substituted for English ball clays with success in most industries, as their colors when burned, bonding strengths, and shrinkages are very similar to those of the imported clays. They are slightly more refractory than the English ball clay, and this must be taken into consideration when such a substitution is made.

The companies that the Bureau of Mines knows to be in active operation in this field at the time this paper is printed are:

Kentucky Construction & Improvement Co., Mayfield, Graves County, Ky.

Cooley, Ball & Sagger Clay Co., Hazel, Calloway County, Ky.

TENNESSEE.

The ball-clay mines in operation in Tennessee are in Henry County in the neighborhood of Paris. The deposits, which are similar to those of Kentucky, consist of several strata of clays that differ slightly in physical and pyrometric properties.

Some of the beds are highly carbonaceous clays that as a rule vitrify at lower temperatures than clays from beds free from carbonaceous material. The noncarbonaceous clays are lower in bonding strength but are superior in color when burned.

These light-colored ball clays of Tennessee have been successfully employed as substitutes for the best English ball clays, and although a slightly larger amount has to be used, owing to the lower bonding power, the product when burned is of superior color. All the ball clays of this district are more refractory than the English ball clays, and must not be expected to produce a body of equal density without the aid of other fluxes.

Tennessee ball clays are extensively used in all the white-ware industries, and especially in the manufacture of electrical porcelain.

The large pits which have furnished the best clays from this district have been robbed of the most marketable clay, and further operations will require the removal of an excessive amount of low-grade material. More pits are being opened in the immediate neighborhood to expose new areas of high-grade clay. As ball-clay deposits may vary in physical properties within short distances, the exact character of material that the new pits will yield can be determined only by test. The clay thus far exposed, however, indicates that the product of the new pits will equal in quality that obtained from the old workings.

No reliable estimate of the future production of American ball clays can be made at this time, owing to the uncertainties connected with the opening of new deposits. The demand will undoubtedly control the production to a great extent. The difficulty of mining an open pit in the wintertime makes it advisable that ball clay desired for use during the winter be obtained before severe weather begins.

So far as the Bureau of Mines has knowledge, the companies mining ball clay in Tennessee at the time this paper is printed are:

Johnson & Porter Clay Co., Paris, Henry County, Tenn.
John Sant & Sons Co., East Liverpool, Ohio.
Mandle Clay Mining Co., St. Louis, Mo.

INACTIVE BALL-CLAY DEPOSITS.

MISSOURI.

Deposits of ball clay near Regina, Jefferson County, Mo., and 12 miles from Victoria, Mo., the nearest railroad station, were worked for several years. Mining was abandoned owing to the introduction of the Kentucky and Tennessee ball clays, which were more easily obtained. The Missouri ball clay is less refractory and more plastic than the Kentucky or Tennessee ball clays but contains considerable iron pyrites, which is scattered through the deposits and make them unsatisfactory for use in most ceramic industries. The clay could be obtained in a reasonable state of purity by hand sorting. It was used for the manufacture of earthenware before regular importation of English ball clay began, and could again be used if necessary.

NEW JERSEY.

The New Jersey deposits are in the neighborhood of South Amboy. The clay is quite plastic but has a low bonding strength and could not be substituted for the European ball clays. It burns to a buff color. This clay is not used at present in the manufacture of white ware of high grade, although it could doubtless be employed in making sanitary ware.

MANUFACTURED WARES.

VALUE OF IMPORTS.

The value of pottery imported by the United States during 1913 was $10,177,451. The value of the total consumption was $47,575,847. This country is, therefore, importing pottery valued at more than 20 per cent of its total consumption.[a]

DOMESTIC TRADE.

REPLACING IMPORTED BY AMERICAN-MADE GOODS.

The present situation as regards the importation of ceramic wares into the United States is worthy of serious consideration by our manufacturers. Many users who have heretofore refused to consider the use of American-made goods have been forced to purchase domestic ware for immediate needs, and the American manufacturer has the long-sought opportunity to prove the merits of his products. A canvass of the industries indicates that small orders only are being placed. Goods are being bought for immediate needs only, in the hope that the European sources of supply will soon be again available. Manufacturers must be extremely careful in handling these orders if permanent business is to develop from them. The necessity of obtaining goods to supply present needs may cause users to accept ware that under ordinary conditions they would reject.

NECESSITY OF MAINTAINING QUALITY OF PRODUCT.

Attempts to increase output or rush production are generally associated with a reduction in quality, and attention is especially called at this time to the importance of maintenance of the highest possible standard.

CONDITIONS CONFRONTING THE EUROPEAN COMPETITOR.

Industrial affairs in Europe will be a considerable time in returning to the condition prevailing prior to the opening of the present war, even though hostilities were to cease immediately. The force of trained workmen will be seriously reduced and many who return will be unfitted, through injuries, to fill their former places. New men must be trained for the work and the number of young men available for such work will be much smaller than heretofore. Operation with inferior or semiskilled labor is especially expensive in the ceramic industries, owing to excessive breakage and the consequent decrease in production.

The heavy expense of restoration will also be added to the other expenses, and the selling price of European ware will doubtless increase.

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[a] Mineral Resources of the United States, calendar year 1913, U. S. Geol. Survey, pt. 2, 1914, p. 109.

OPPORTUNITY OF AMERICAN MANUFACTURERS.

These conditions will directly benefit the American manufacturer. Competition will be one of quality rather than price. The European manufacturer must not be expected to relinquish his American customers without a great struggle. The lack of money in Europe will make American business especially attractive to him and new business will be sought to replace the European business lost.

The American manufacturer has now no foreign competition in his own country, but is assured of a return of such competition within a reasonable time under conditions more favorable to him than heretofore. It remains to be seen whether our manufacturers will profit by the opportunities that they now enjoy.

IMPROVEMENT IN METHODS NEEDED.

At this time especial attention is called to the wasteful practices that are too common in American factories. This refers to both material and labor. Factory arrangements are such in many plants that the ware must pass the same point many times in the manufacturing process. If the ceramic manufacturer of the United States will make a sincere effort to come up to the European standard of quality and efficiency, he should be able to compete successfully for all the business of this country.

EXPORT TRADE.

Ceramic manufacturers of the United States are just beginning to appreciate the possibilities of the export trade. Practically all the demand from South America has been supplied by Europe heretofore. This demand is now unsupplied owing to conditions in Europe and can be temporarily filled by the United States with little effort. Once obtained, however, it should be our aim to handle this business so that it will not return to the foreign source of supply when the opportunity is provided.

This will require not only a careful study of the special requirements of foreign customers, but special attention to their methods of transacting business. If this business is attractive to the European manufacturer, it can certainly be made attractive to the manufacturer in the United States.

PUBLICATIONS ON MINERAL TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

Bulletin 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

Bulletin 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs.

Bulletin 19. Physical and chemical properties of the petroleums of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the Southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

Bulletin 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

Bulletin 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

Bulletin 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

Bulletin 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 170 pp., 16 pls., 12 figs.

Bulletin 60. Hydraulic mine filling; its use in the Pennsylvania anthracite fields; a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

Bulletin 64. The titaniferous iron ores in the United States; their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

Bulletin 70. A preliminary report on uranium, radium, and vanadium, by R. B. Moore and K. L. Kithil. 1913. 101 pp., 4 pls., 2 figs.

Bulletin 71. Fuller's earth, by C. L. Parsons. 1913. 38 pp.

Technical Paper 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

Technical Paper 41. Mining and treatment of lead and zinc ores in the Joplin district, Mo., a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

Technical Paper 55. The production and use of brown coal in the vicinity of Cologne, Germany, by C. A. Davis. 1913. 15 pp.

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